

INTRODUCTION The map shows the location and relative magnitude of deposits and occurrences of manganese, a metal which is used primarily as an additive in steel to facilitate removal of impurities as a slag (waste) fraction during the refining of ore, and as an alloy material in steel to increase strength and workability. There are no substitutes for manganese in steelmaking. The apparent consumption of manganese metal in 1978 was approximately 1.4 million short tons (about 1.3 million metric tons). The nation imported 98 percent of the primary manganese required that year, mainly from Brazil, Gabon, Australia, and South Africa; the remainder was from industry stockpiles (U.S. Bur. Mines, 1979). Recycling of both slag and scrap materials to recover manganese provided an insignificant portion. Because of the projected increase in demand for manganese of about one-third by the year 2000 (DeHuff, 1975), there may be a greater future concern about domestic sources, particularly if current import The United States has no domestic supply of minable manganese (ore) materials but has a substantial potential for subeconomic sources of this metal. The main problem with regard to domestic manganese resources is that the large deposits are generally subeconomic because of their low grade and (or) refractory character. The high-grade deposits, which are more numerous in the United States, are small and are uneconomic to mine for manganese alone. Higher grade minable manganese minerals are more economically available overseas. There seems to be little hope, on the basis of present geologic data, to expect to discover or utilize large-scale high-grade concentrations of manganese minerals from previously known manganese mining districts in the conterminous United States; however, more disseminated domestic sedimentary geologic environments that are comparable with productive ones in Russia and Australia have not been evaluated. There is a possibility that resource investigations in these areas would result in discoveries of large low-grade manganese concentrations worthy of further exploration. Recovery of high-grade manganese as a byproduct material during mining for associated metals could also add to the domestic resource. If metallurgical technology and economic factors improve, or strategic and industrial needs require it, a search for additional hypothetical resources in the United States may be worthwhile. The purpose of the province map is to show where additional geologic search may most profitably be made. Manganese constitutes about 0.1 percent of the Earth's crust and is more abundant in mafic rocks than in granitic types. To be economic a deposit must contain between 25 and 50 percent manganese, which means that a concentration of from 250-500 times crustal background is required to form an economic deposit (Dorr and others, 1973). The chemical properties of manganese are similar to iron, thus their geologic occurrences are commonly closely related. The main ore minerals of manganese are oxides and carbonates that are concentrated in a variety of fresh and altered sedimentary rocks in hydrothermal vein and replacement bodies, and in seabed nodules.

The map was compiled from published reports (Pearre, 1956, 1961; Huntting, 1956; Crittenden and Pavlides, 1962; Crittenden, 1964a, b; Prinz, 1964; U.S. Geol. Survey, 1964; Haigler and Sutherland, 1965; Davis and Hewett, 1966; Dorr and Sweeney, 1968; Dorr, 1969; Georgia Dept. Mines, Mining, and Geology, 1969; Anderson, 1973; Gries, 1975) and records of the U.S. Geological Survey's manganese resource specialist. Geologic background data used in defining province boundaries are from the geologic map of the United States (King and Beikman, 1974). Some of the technical terms and geologic concepts used in the atlas of metal and nonmetal provinces, of which this report is a part, are discussed and defined in a companion background report by Tooker (1979b).

DISTINGUISHING MAP FEATURES The map shows the distribution of 33 manganese provinces and tentative provinces, which are broad areas that contain or are expected to contain anomalous amounts of the metal well above its crustal abundance. A summary of current information about, the size and main geologic types of occurrence, as well as estimates of future resource possibilities, are shown in table 1. The purpose of the province map is to identify regions in the conterminous United States where manganese has been or may be produced either as a primary or byproduct material, together with an assessment of the current status of geologic resource information to aid in evaluating the potential availability of resources in each A manganese province is a geographic area characterized by deposit and occurrence localities containing relatively high or broadly disseminated lower grade concentrations of primary or byproduct metal. No distinction is made between the economic and subeconomic character of deposits or occurrences in the definition of provinces. Province boundaries enclose areas containing localities ranging in size from a single mine to a broad regional mining district or belt, or known presently subeconomic occurrence; in some cases a province encloses the outcrop area of geologic rock formations believed to have been favorable hosts for the concentration and deposition of manganese. In some provinces the overlap or mixing of geologic types suggests that geologic conditions may have changed with time, and that manganese was remobilized and redeposited. Where possible, the province boundary is drawn on the basis of geologic units or structures, and, as a result, some provinces may consist of a number of detached areas. In some cases, boundaries may enclose broadly favorable geologic regions that adjoin plotted localities, but in other cases, where areas of favorability are less certain, we have inferred possible extensions of provinces (by number and query) without a boundary. Where prominent mappable features are not present, province boundaries have been drawn about localities that seem to share common geologic characteristics. Finally, there are a number of solitary and isolated localities that do not seem to fall into a known regional geologic pattern. When such presently poorly defined areas are studied systematically, they may indeed turn out to have no resource significance, but if more manganese concentrations are located as a result of more information, these areas may become recognized as potential new manganese provinces. The purpose of the province map is to identify such possibilities and help narrow the area of search for manganese during a national Deposits and occurrences of manganese are classified on this map on the basis of past production, minable minerals, if any, expected potentially minable materials, and production activity in 1975 production and potentially minable materials exceed 5 million long tons (>5 million metric tons) of contained manganese, which, for sake of comparison in the atlas, would be valued at more than \$1 billion in 1978. Such a deposit represents about a 4-year supply, based on reported consumption in 1978 (U.S. Bur. Mines, 1979). In the atlas (Tooker, 1979b), large deposits are subdivided into those that were active mines (type A) and inactive deposits (type B) during the 1975 base year, as determined from U.S. Geological Survey information and as reported also in an international survey of mining (Mining Mag. 1976). Because there was no production of manganese in 1975, no large active type A deposits can be shown. There were, however, a number of large inactive type B deposits which for the most part represent former large producers that are now mined out or are inactive, but believed to contain additional subeconomic potentially minable resources. The large solid dot type B localities show where the metal was formerly produced, the large open dots show where there is potential for

provinces. By definition their combined production and potentially minable materials aggregate less than 5 million long tons of contained manganese, or they are unevaluated, depending on the level of geologic knowledge available. In most cases type C deposits contain small but high-grade bodies of ore which have been generally uneconomic to mine as a primary commodity. A few might at some future time yield manganese economically as a byproduct. The map also pinpoints some geologic regions that are characterized by more or less specific geologic settings in which manganese was concentrated in crustal rocks. The geologic processes that concentrate manganese are varied; some are a result of low-temperature hydrothermal solutions and meteoric waters acting on sedimentary and igneous rocks in the subsurface. In other areas manganese was a minor constituent of sedimentary rocks, and was later reconcentrated by oxidation, weathering, and subsequent erosion at the surface. The deposit types formed are similarly variable. Large, lowgrade oxide accumulations were formed by deposition in open pore spaces, veins, and breccia zones, by replacement of carbonate rocks, or as nodules on the sea floor. Lenticular high-grade deposits of oxide, carbonate, and silicate minerals may form in eugeosynclinal basins adjacent to nearby submarine volcanic sources. Less commonly manganese occurs as carbonate concretions in shales, the result of physical-chemical concentration processes that occurred during the lithification of the host rock. Hot spring waters have deposited small low-grade alluvial fan and playa accumulations.

Small deposits or occurrences, classed as type C, predominate in most of the manganese

In contrast are the manganese deposits formed by low- to medium-temperature hydrothermal solutions derived from processes accompanying the formation of intrusive igneous bodies. These solutions concentrated manganese along with associated base and precious metals. Oxide, carbonate, and silicate manganese minerals were deposited in open vein structures and also may have replaced the intruded host rocks. In zoned base-metal deposits manganese is commonly in the outermost zone, and rock alteration is often associated with such deposits. Oxide vein deposits may also be closely associated with Cenozoic volcanic rocks. Contact skarn deposits in sediments intruded by igneous plutons may also contain manganese. Description of typical examples of all of these deposit types and references to additional details about their occurrence are in reports by Dorr and others (1973) and Stanton (1972). Observations (Noble, 1976; Guild, 1978; and Tooker, 1979a) that metal provinces seem to occur in distinctive patterns in different parts of the exposed crust is also recognized in the manganese province map. The pattern of province distribution seems to be correlatable with formation of deposits either in an interior old continent crust composed of Precambrian basement and Phanerozoic cover rocks or in oceanic and island-arc accreted crust marginal to the coastline composed of Phanerozoic rocks (Tooker, 1979b).

Manganese provinces, which occur in rocks that overlie both the old continent and oceanic crustal plates, are found mainly in the Cordilleran and Appalachian belts. The metal also occurs locally in the Central Plains and Precambrian shield as well as offshore on the Blake Plateau. Thirty-three provinces or potential province areas are shown on the map, and their geologic and resource characteristics are summarized in table 1. Most manganese deposits or occurrences lying in oceanic-derived crustal rocks are localized in stratiform and weathering enriched stratabound bodies, the result of volcanogenic and sedimentary processes. The geologic distribution of these resource materials seems to follow preferred stratigraphic horizons and structures in the accreted oceanic terranes. They trend northerly parallel to the coastline in provinces 7, 14, and 25 in California and western Oregon, swinging to the east in province 30 in eastern Oregon. The deposits in province 6 are also of this type, but those in 6a occur in a crystalline terrane of uncertain origin. The size of the known individual deposits that occur in oceanic crust along the Pacific coast is too small for economic development in spite of the large numbers of localities. The few exceptions have already been mined out. In contrast are the large (type B) deposits apparently in oceanic-derived volcanogenic rocks in province l in northern Maine. Province 27 in oceanic-derived rocks of the southern Atlantic coast may contain similarly derived occurrences of manganese, but they are generally small and not fully known. Cordilleran belt and Colorado Plateau manganese localities in the old continent crust define northeast-trending provinces or groups of provinces (i.e., 3 and 22; 26, 23, 9; 19, 2, 16, 18, and 18a; 15, 23, and 17, and 8), geologic types of manganese occurrences are distinctively different from oceanic plate deposits, for the most part. Although a few manganese provinces are indicated within the Colorado Plateau, a great number of them seem to be clustered around its margin. Deposits and occurrences within the Central Plains region, in provinces 4, 5, 10, 11, 20, 20a, 21, 24, 31, and 32, are mostly of stratabound sedimentary and hydrothermal types; and most have been enriched by weathering processes. Province 4 contains large low-grade resource (Crittenden and Pavlides, 1962); however, there has been no past production from contained manganese nodules, and the U.S. Bureau of Mines rates such deposits as having a very low economic potential because of present technologic and environmental extraction and processing problems. The Appalachian belt deposits and occurrences are found mainly in early to middle Paleozoic stratabound ferruginous shales, slates, and ironstones (province 1) and breccia fillings and replacements in clastic rocks (provinces 12 and 29) that have been enriched by the weathering of lowgrade manganese-bearing sediments during prolonged erosion. Deposits in provinces 27 and 28 are residual oxides in clay deposits derived from limestone or dolomite. Most of these localities have been examined by the U.S. Geological Survey and found to be too small for successful recovery of primary manganese. Their potential for byproduct production does not seem great in most cases, except in the stratabound type which may be areally large. Low-grade stratabound accumulations also were formed in or near the iron formation in the Precambrian Cuyuna Range, Minn. (province 5). The potential of these deposits is believed to be substantial. At least one type B deposit is already known. Manganese nodules lying within the 200-mile territorial limits of the conterminous United States occur on the Blake Plateau, off the coast of Florida and Georgia in tentative province 33. This potentially large but undefined occurrence area has been considered a domestic resource (Natl. Materials Advisory Board, 1976). If deep ocean seabed mining operations begin in the next decade, the manganese resource picture will drastically change, virtually eclipsing all known domestic land resources. If recovered, the manganese will be a coproduct or byproduct of mining the much more valuable metals such as nickel, cobalt, chromium, and vanadium. Thus, while manganese may not be recovered initially, the tailings from nodule processing will constitute a vast resource of high-grade mined and milled material conveniently transported to processing facilities. Two or three nodule operations could produce manganese at a rate sufficient for projected domestic consumption.

On basis of broad geologic grounds, several parts of the United States are judged to have potential for undiscovered (hypothetical) manganese deposits. But because these areas contain no presently known occurrences, they are not shown on the map. In this category we include the sedimentary environment of the Coastal Plains along the Atlantic Ocean and Gulf of Mexico, and Cretaceous sediments in parts of the Central Plains in the upper midwest peripheral to the exposed Precambrian shield. Portions of these areas have strong geologic affinities with areas in the Soviet Union and Australia, where comparable rock sequences contain large sedimentary type deposits. In the United States such areas have not been well explored for manganese and represent locations for resource evaluation to find heretofore speculative, locally restricted concentrations in these sedimentary sequences. Because this is now only a vast very tenuous area, no provinces can be shown.

## Scale 1:5,000,000 100 0 100 200 300 400 Mile 100 0 100 200 300 400 500 Kilometers

## PRELIMINARY MAP OF MANGANESE PROVINCES IN THE CONTERMINOUS UNITED STATES

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Background information relating to this map and others in the Atlas of Metal and Nonmetal Provinces in the Conterminous United States is published as U.S. Geological Survey Circular 792 (Tooker, 1979), available free of charge from the U.S. Geological Survey, Branch

of Distribution, 1200 Eads St., Arlington, VA 22202.

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

Table 1.--Locations, type of deposits, estimates of resource potential, and status of resource information

Province location			Geologic types of	Preliminary estimates of resource potential <sup>2</sup>			Status of geologic resource information	
No.	State	Area	deposits 1	High	Medium	Low	Adequate	Inadequat
1	Maine	Aroostook Co.	I, III	χ			Χ?	
2	Arizona	Artillery Peak	I	Χ			Х	
3	Idaho and Montana	Butte	II	χ				х
4	Minnesota	Cuyuna Range	I, III		Χ			Х
5	South Dakota	Pierre Shale outcrops (Chamberlain dist.)	I	Х			X	,
6	Washington	Olympic Peninsula	I		Х?		Х	
6a	Do	Northern border	II, III?			Χ		X
7	California	Coast Ranges	I		Χ?		Х	
8	New Mexico	Rio Grande rift zone	II		X?			Х
9	Utah and Nevada	Great Basin	II		Х			Х
10	Arkansas	Batesville	I, II, III		Χ			X
11	Oklahoma and Arkansas	McCurtain and Polk Counties	II, III		Χ			Х
12	Alabama, Georgia, Tennessee, Virginia Maryland and Pennsylvania	Appalachian Mountains	I, III		Х		Х	
13	Arizona	Southern Colorado Plateau				X		X
14	Oregon and California	Klamath Mountains	I			X	Χ	
15	Arizona	South-central	II			Х		Х
16	Utah and Colorado	Northern Colorado Plateau	I			Х	·	Х
17	Colorado	Front Range mineral belt	II		χ			X
18	Wyoming and South Dakota	Black Hills	I			X		Х
18a	Wyoming	Central Wyoming	I			Χ		X
19	California and Arizona	Mojave and Colorado River	II			Х		X
20 20a	Texas Do	South-central Southwest	I			X		X
21	Oklahoma	Bromide	 II			X		Х
22	Nevada	Central	I, II			X		Х
23	Do	Southern	I, II			X		Х
24	Missouri	Southeast				X		Х
25	California	Sierra foothills	I, II, III I			X?		Х
26	Do	Northern Mojave Desert	I			X	X	
27	North Carolina, South	Piedmont	I, III			X		X X
28	Virginia	Blue Ridge	I, III			Χ		х
29	New Jersey	Franklin Furnace	II			X	X	^
29a	Massachusetts	Hampshire County				X		X
30	Oregon	Northeastern	I			Χ		Х
31	Tennessee	Western	I, III			χ		Χ
32	North Dakota	Mineral Springs	I			χ		X
33	Offshore	Blake Plateau	IV		unknown			Х

<sup>1</sup>Main types of deposits (based on Crittenden and Pavlides, 1962).

I. Sedimentary or volcanogenic stratabound and stratiform deposits; lenticular or blanket deposit.

II. Hydrothermal vein and replacement deposit as a major or gangue mineral; includes hot spring deposits.

III. Enrichments by supergene and weathering processes; oxide open-space filling and replacement.

<sup>2</sup>A <u>high</u> estimate indicates the presence or expectation of more than one large (type A or B) deposit, a <u>low</u> estimate is based

IV. Manganese nodule deposits, both sea bed and fossil types.

on the presence of type C deposits and (or) occurrences.

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